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TECHNICAL REPORT

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RESULTS FROM TRIALS OF A NEW YAWSONDE DESIGN

R.L. POPE

Approved for Public Release

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WSRL

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RESULTS FROM TRIALS OF A NEW YAWSONDE DESIGN

R.L. Pope

SUMMARY

A series of three trials has been conducted using artillery shells fitted with yawsondes. The first two yawsondes were manufactured from a new Weapons Systems Research Laboratory design while the third yawsonde was supplied by the Ballistic Research Laboratory, USA. These were the first trials of the WSRL design and provided useful data for the first quarter of the flight of the shell. Analysis of the data was somewhat hampered by the absence of trajectory data and of accurate calibrations for the WSRL yawsondes; however, some useful results have been obtained from the data analysis and these are reported here. The report includes a brief description of the trial conditions and a summary of suggestions for improving the quality and usefulness of the data obtained from subsequent trials.

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A series of three trials has been conducted using artillery shells fitted with yawsondes. The first two yawsondes were manufactured from a new Weapons Systems Research Laboratory design while the third yawsonde was supplied by the Ballistic Research Laboratory, USA. These were the first trials of the WSRL design and provided useful data for the first quarter of the flight of the shell. Analysis of the data was somewhat hampered by the absence of trajectory data and of accurate calibrations for the WSRL yawsondes; however, some useful results have been obtained from the data analysis and these are reported here. The report includes a brief description of the trial conditions and a summary of suggestions for improving the quality and usefulness of the data obtained from subsequent trials.

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1. INTRODUCTION

Instrumentation and data analysis methods for studying the flight behaviour of artillery shells are being developed as part of a programme of research into the exterior ballistics of shells. They will be used to study the flight characteristics of shells which are exhibiting rogue behaviour or, in the case of new or modified designs, they will provide a quick, simple method of assessing stability. They may also be used as part of improved cheaper methods for developing Fire Control Models for artillery systems. Computer programmes have been written(ref.1) to analyse yawsonde and trajectory data from shell flights. The programs have been tested using data obtained from two yawsondes at Woomera(ref.2). These yawsondes were supplied by Ballistic Research Laboratory (BRL).

Yawsondes, which were designed and developed at Weapons Systems Research Laboratory (WSRL), have now been used to obtain data from flights of the 105 mm, HES, M1 artillery shell. A series of three trials was conducted at the Proof and Experimental Establishment, Port Wakefield on 20th of February 1979. The first two shells carried WSRL yawsondes and the third carried a BRL yawsonde. Useful data was obtained from all yawsondes, although the complete trajectory was not covered by any of them. This was the first flight test of the WSRL designed yawsondes. The trials also aimed to evaluate trajectory data from the AN/KPQ1 tracking radar situated on the range. However, a malfunction in the tape recorder resulted in the complete loss of one coordinate and, consequently, the trajectory data was unusable. It was possible to salvage something from the trials by using a theoretical shell trajectory. Although this meant that much of the accurate data generally available from yawsonde trials was missing in this case, the approximate trajectory data enabled us to salvage some results from the trials. In particular, the results demonstrate the high quality of the data obtained with the WSRL yawsondes. This paper summarises the trial conditions, reports in some detail on the data obtained from the trial and makes some recommendations on gathering and analysis of data from future trials.

2. TRIALS

A total of six M1 shells was fired at Port Wakefield. The first three were barrel warmers and were tracked satisfactorily on radar from the look-in point at 4 s along the trajectory to about 25 s, which was just past apogee. All shells were fired at charge 5, with a nominal muzzle velocity of 301.8 ms^{-1} with an elevation of 45°. Everything functioned satisfactorily on the barrel warmers although no attempt was made to record any data, and so the trials involving the three yawsondes were commenced. Physical data on each of these rounds, C49, C52 and C53, is given in Table 1, together with yawsonde serial numbers and times for each firing.

Yawsonde calibration data is given in Table 2. The theoretical relationship(ref.1) between the complementary solar aspect angle, that is, the angle between the normal to the shell spin axis and the sun direction, σ_N, and the ratio of pulse times from the yawsonde is given by

$$\tan \sigma = -\sin(2\pi\tau/T + \beta)/[\tan^2\gamma_2$$
$$- 2 \tan \gamma_1 \tan \gamma_2 \cos(2\pi\tau/T + \beta)]^{1/2}$$

where τ is the time interval separating the pulse from slit 1 and the pulse from slit 2, T is the time interval separating successive pulses from slit 1, that is, the roll period, γ_1, γ_2 are the angles which each slit makes with the longitudinal axis of the shell and β is the circumferential angle separating slits 1 and 2. Accurate direct measurement of the angular parameters γ_1, γ_2 and β is a difficult task and it is preferable to measure the variation of the

TABLE 1. PHYSICAL DATA

	C49	C52	C53
mass (kg)	14.68	14.69	14.70
C.G. (m from base)	0.1785	0.1798	0.1797
roll inertia (kg m^2)	0.0229	0.0227	0.0226
pitch inertia (kg m^2)	0.215	0.218	0.218
diameter (m)	0.105	0.105	0.105
yawsonde	SN1036	WSRL01	WSRL05
firing time (GMT)	23:58:30	23:37:35	23:47:33

TABLE 2. CALIBRATION DATA

(a) Theoretical curves

	C49	C52	C53
γ_1	29.282	47.0	46.9
γ_2	-29.336	-52.1	-49.8
β	84.462	80.7	96.4

(b) Polynomial for C49

a_0	-114.2501
a_1	866.1462
a_2	-5056.9442
a_3	14358.8708
a_4	-16982.9212
a_5	7070.0150

complementary solar aspect angle, σ_N, as a function of the ratio τ/T. Unfortunately a calibration rig to carry out such measurements is a sophisticated and costly piece of equipment(ref.3) and a makeshift rig had to be used for the WSRL yawsondes. The theoretical relationship specified above was fitted to the limited data recorded for these yawsondes and the parameter values given in Table 2(a) were obtained. These parameter values should specify the calibration to better than two degrees over the whole range. It will be necessary at some later stage to improve this accuracy substantially in order to realise the full potential of the yawsonde.

The second part of Table 2 defines the calibration curve for the BRL yawsonde in the form of a polynomial,

$$\sigma_N = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5$$

where $x = \tau/T$ is the ratio of times described above. The polynomial coefficients were supplied with the yawsonde by Ballistic Research Laboratory and provide a highly accurate means of obtaining the complementary solar aspect angle from measurements of the time between pulses.

The main purpose of the trials was to test the WSRL yawsondes in flight, to record and analyse the data obtained from them and to determine the quality and usefulness of the results of the parameter estimation process described in reference 1. From this point of view the trials were a complete success, but some of the secondary aims of the trials met with mixed success. The radar failed completely to acquire one of the shells, C53, and although it tracked for about 25 s of the flight of the other two shells one of the recording channels malfunctioned so that no record was obtained of the OZ coordinate. Consequently, no useful radar data could be obtained from the trial record. However, limited analysis of the yawsonde data was possible, using a theoretical trajectory generated by a six degree of freedom model with nominal values for the gun elevation and muzzle velocity. The results of this analysis are discussed in the next section.

3. RESULTS

Both roll rate and complementary solar aspect angle can be derived from yawsonde records. Unlike the derivation of the complementary solar aspect angle, deriving the roll rate from the yawsonde data does not involve any calibration. Hence the roll rate information obtained from all three yawsondes is accurate. On the other hand because only an approximate calibration could be carried out for the two WSRL yawsondes it was possible to make a detailed analysis of the solar aspect angle data only for the BRL yawsonde. Two related error sources are common to results derived from both roll and aspect angle data. Both arise from the lack of trajectory measurements. First there is the absence of the trajectory data itself, particularly velocity, dynamic pressure and Mach number. Although this deficiency can be compensated for by using a theoretical trajectory based on the nominal values for gun elevation and muzzle velocity, a second problem arises because no accurate measurement is available for the firing time of each shell. The estimates given in Table 1 may contain errors of as much as 2 or 3 s. These problems are discussed further below and means of compensating for them are discussed in Section 4. In order to minimise the complications arising from calibration and trajectory inaccuracies we will consider the roll rate and aspect angle measurements separately.

3.1 Roll rate

The roll rate data is obtained directly from the yawsonde data without the need for any calibration. However, in order to derive values for roll damping coefficient derivative, dynamic pressure and Mach number data are required. Although relative timing between yawsonde data and theoretical trajectory is a problem, a maximum error of one or two seconds in trajectory timing should cause an error no larger than a few percent in the roll damping coefficient derivative.

The data was analysed by the method described in reference 1. The roll damping derivative is represented by a polynomial in Mach number, which has the form

$$C_{l_p} = a_o + a_1M + a_2M^2 + a_3M^3.$$

Provision is made for terms as high as the cubic term shown above to be used, but there was no significant improvement in fitting to the measured roll rate for the three trials analysed here using anything more than a linear representation. The results of the analysis are given in Table 3 and figure 1. Table 3 shows values of the coefficients a_0 and a_1 as well as the initial roll rate, p_o, the mean square root of the difference between measured roll rate values and mathematical model output, σ, and the Mach number range of the data. The figures in brackets beneath each parameter value are the estimated standard deviation of the error in each parameter value. A comparison of results from these trials with similar results from previous trials(ref.2) and with wind tunnel measurements(ref.1) shows fair agreement, only. The discrepancy between the results from different sources is generally larger than the scatter of individual results from the same source, except for high subsonic Mach numbers. The scatter of individual results is quite consistent with the estimated values for the standard errors in the parameters. It should be remembered in assessing results from the rounds C49, C52 and C53, relative both to those from previous trials and to the wind tunnel measurements, that the data analysis relied on a simulated trajectory rather than a measured one. As a consequence, they may be subject to significant errors and so some caution should be exercised when attempting to draw conclusions from any differences.

TABLE 3. RESULTS FROM ROLL RATE MEASUREMENTS

	C49	C52	C53
p_0(rad/s)	966.1 (0.055)	910.2 (0.054)	914.9 (0.094)
a_0	-0.02658 (0.00023)	-0.02860 (0.00040)	-0.03147 (0.00079)
a_1	0.00272 (0.00040)	0.00744 (0.00053)	0.01035 (0.00105)
σ (rad)	0.3963	0.4613	0.7711
M_0	0.53	0.6	0.6
M_1	0.80	0.89	0.89

3.2 Solar aspect angle

Complementary solar aspect angles derived from the trials with the two WSRL yawsondes are shown in figure 2. These results were obtained using the approximate calibration curves defined by the parameter values given in Table 2. Further analysis of these results was not worthwhile since the combination of errors arising from the calibration and the lack of measured trajectory data would have rendered any results from the parameter identification process described in reference 1 of doubtful significance.

Data was obtained only for the first third of the trajectory for both WSRL yawsondes in contrast to the 30 s of data obtained from the BRL yawsonde. This indicates that some effort will be needed to improve the received signal strength in order to obtain data from a shell over the whole of its trajectory. This can probably be achieved with increased experience of trials personnel and some minor improvements to the receivers. However, all the data obtained from the yawsonde in round C52 and the first half of the data obtained from the yawsonde in round C53 was of very good quality. Therefore, only a slight improvement of received signal strength should be needed.

The results obtained with the WSRL yawsondes depicted some interesting behaviour on the part of the shell. The most obvious aspect in both parts of figure 2 is that the precession is undamped. In figure 2(a), the shell commenced its flight quite normally with an amplitude of about 2° and frequency of 1.6 Hz in the precession mode and an amplitude of about 0.2° and a frequency of about 13 Hz in the nutation mode. Both precession and nutation were adequately damped initially, but after about 3 s the precession amplitude began to grow and continued to do so throughout the length of the record, although it appeared to be approaching neutral stability or a limit cycle towards the end of the record. In figure 2(b) the shell commenced its flight with precession, and nutation of similar amplitude and frequencies and while the nutation damped slowly the amplitude of the precession increased markedly. Although the noise and signal dropouts in the second half of the record make it difficult to assess the behaviour, the overall conclusion is that both rounds were unstable with regard to precession at least initially. The results from the BRL yawsonde in round C49, which are shown in figure 3 are also consistent with this behaviour. While the nutation is very lightly damped, the precession is at best only neutrally stable.

Since an accurate calibration was available for the BRL yawsonde in round C49, this data warranted some further quantitative analysis by parameter identification. Therefore a trajectory was generated from a theoretical model using nominal values for muzzle velocity and gun elevation and was used to supply values of velocity components, dynamic pressure and altitude above sea level needed for the parameter identification process. The results of the initial run are shown in figure 3(a). Although the parameter identification algorithm has successfully matched the precession in both amplitude and frequency, the simulated data is displaced from the measured data by between three and four degrees. The majority of this discrepancy probably arises from errors in the timing of the data relative to the instant of fire. Figure 3(b) shows the results of a similar run with the timing adjusted by 2.5 s. There is much better correspondence between measured and simulated data in this case although the simulation does not adequately represent the nutation mode, and the centre of oscillation of the precession mode in the simulation drifts slowly relative to the measured flight values. The difference approaches one degree at 10 s. It is likely that representation of the nutation could be improved but the overall accuracy of all the data combined with the small amplitude of the nutation would render valueless the results of such an attempt. The drift of the centre of oscillation of the precession is probably due to accumulated errors in the trajectory data as the discrepancy between the theoretical and the actual trajectory increases with time.

The parameter values obtained with the results in figure 3(b) are listed in Table 4. The estimated standard deviation of the error in each parameter value is given brackets beneath the value, and the root mean square value of the differences between simulated and measured solar aspect angles is given at the bottom of the table. Considering the many uncertainties in the data the results in Table 4 for the pitching moment derivative are good and they compare well with the wind tunnel measurements of $C_{m\alpha}$, quoted in the right hand column of the table. Estimates could not be obtained for both pitch damping derivative, C_{mq}, and Magnus moment derivative, $C_{np\alpha}$, owing to the very small amplitude of the nutational component of the motion. When the nutational component has only small amplitude the effects on solar aspect angle simulation of pitch damping and Magnus moments are very similar. Thus, if there is an attempt to estimate both simultaneously, the parameter identification process becomes unstable because a change in Magnus moment derivative can be compensated for almost exactly by an appropriate change in pitch damping derivative so that the resulting simulation of the complementary solar aspect angle remains virtually unchanged.

TABLE 4. RESULTS FROM ASPECT ANGLE MEASUREMENTS WITH C49

Parameter	Value	Wind Tunnel Measurements
Ψ_o(rad)	-0.0325 (0.0012)	
ϑ_o(rad)	0.6760 (0.0010)	
q_o(rad/s)	0.191 (0.038)	
r_o(rad/s)	-0.225 (0.038)	
$C_{m\alpha}$	3.510 (0.003)	3.8
C_{mq}	0. -	-12.0
$C_{np\alpha}$	0.0536 (0.0148)	0.025
σ(rad)	0.0089	

Finally, the results in figure 3(b) and Table 4 are a good example of a problem which is particularly likely to occur in the application of parameter identification procedures to yawsonde data. This is the problem of local minima. The complementary solar aspect angle measured by the yawsonde is essentially a one-dimensional representation of a two dimensional motion and it is therefore a very limited representation in some respects. A consequence of this is that in reconstructing the original motion through minimising the difference between simulated and measured complementary solar aspect angle records the parameter estimation algorithm may converge to a local minimum. Such convergence is generally characterised by the almost complete absence of either the nutational or the precessional components or both from the simulated aspect angle records. In the case of figure 3(b) nutation is absent. Because the amplitude of this component in the measurements is quite small the local minimum represented by the parameter values in Table 4 will not be far from the desired minimum. Problems with convergence to local minima can usually be rectified by adjusting initial estimates of the parameters ψ_o and ϑ_o when precession is absent or q_o and r_o when nutation is absent. Generally, the amplitude of precession is controlled by the initial incidence of the shell, while the amplitude of nutation is controlled by the initial rate of change of incidence.

4. CONCLUSIONS

The results obtained with the first two WSRL yawsondes are highly satisfactory. Unfortunately, the recording of trajectory data did not match the excellence of the yawsonde performance, although the problem with recording trajectory data can be easily rectified for future trials. It is recommended that in future trials both muzzle velocity and instant of fire be recorded as additional trials data. They would be used to provide back-up trajectory data by an accurate theoretical trajectory generated from a six degree of freedom computer model, in the event that radar tracking data was lost. The muzzle velocity can be measured with the Ferranti Doppler radar which is installed at Port Wakefield for that purpose and the sound from the gun firing can be recorded on one or more channels of the tape recorder to define the instant of fire accurately.

It is clear from the discussion of results in Section 3 that the data loses much of its usefulness if no accurate calibration of the yawsonde is available. The development of a calibration rig such as that described in reference 3 is a non-trivial undertaking, but the calibration of yawsondes to within 0.2° is essential if the potential applications for yawsondes are to be fully realised both with regard to the range of experiments for which they are useful and the data which can be extracted from a given experiment.

Information which has not been discussed in this report but which will become increasingly important(ref.2) as the accuracy of other data components improves is that provided by the meteorological report. Further thought will have to be given to the measurement of meteorological data when the more pressing problems of accurate trajectory data and accurate yawsonde calibration have been solved.

Another problem which will increase in importance as other problems are solved is the strength of the signal received from the yawsonde. There are two aspects of this problem. Firstly, since a good signal was received right up to impact from BRL yawsondes over similar ranges at Woomera(ref.2), it should be possible to improve reception. This can probably be achieved by further trials to increase the experience of the operators and by some minor improvements to the receivers. It may also be possible to improve the gain of the receiving aerial although this will narrow the beamwidth and may present problems in tracking the shell. The second avenue open is to increase the transmitter power, if future trials show that receiver improvements are insufficient to meet requirements.

Finally, one of the most interesting aspects of the data analysis is the tendency for the parameter identification algorithm to converge to local minima. Initial attempts at analysing the BRL yawsonde data resulted in motion from which both precession and nutation were absent. Further attempts with modified initial estimates of parameter values showed that both precession and nutation could be excited by altering initial estimates of the appropriate parameters. The effects of initial conditions on the amplitude of the precessional and nutational components of the angular motion of the shell can be easily extracted from the solution of the linearised equations describing the angular motion of the shell(ref.4). It is clear from the solution that the amplitude of the precession is controlled by the initial incidence of the shell whereas the amplitude of the nutation is controlled by the initial rate of change of the incidence, that is, the pitch and yaw rates.

5. ACKNOWLEDGEMENT

Mr A.D. Hind and Mr C.J. Beach of Field Experiments Group have both made substantial contributions to the work reported here. They designed and developed the WSRL yawsonde and organised the trials.

NOTATION

a_i	coefficients of polynomials
$C_{lp}=\partial C_l/\partial(pd/2V)$	derivative of roll damping moment coefficient
$C_{mq}=\partial C_m/\partial(qd/2V)$	derivative of pitch damping moment coefficient
$C_{m\alpha}=\partial C_m/\partial\alpha$	derivative of pitching moment coefficient
$C_{np\alpha}=\partial^2 C_n/\partial(pd/2V)\partial\alpha$	derivative of Magnus moment coefficient derivative
M	Mach number
p	roll rate
q	pitch rate
r	yaw rate
T	roll period (time interval between pulses from same slit)
α	total incidence of shell
β	circumferential angle between yawsonde slits
γ_i	angle between each yawsonde slit and shell axis
ϑ	elevation of shell axis
σ	root mean square value of differences between simulated and experimental outputs
σ_N	complementary solar aspect angle
τ	time interval between pulses from different yawsonde slits
ψ	azimuth of shell axis

subscripts

o	denotes initial conditions

REFERENCES

No.	Author	Title
1	Pope, R.L.	"The analysis of trajectory and solar aspect angle records of shell flights. Theory and computer programs". WSRL-0039-TR, September 1978
2	Pope, R.L.	"Initial results in developing free flight testing techniques for artillery shells". WSRL-0165-TR, July 1980
3	Mermagen, W.H.	"Measurements of the dynamical behaviour of projectiles over long flight paths". J. Spacecraft and Rockets Vol.8 No.4 pp380-385, April 1971.
4	Murphy, C.H.	"Free flight motion of symmetric missiles". BRL Rpt 1216, 1963

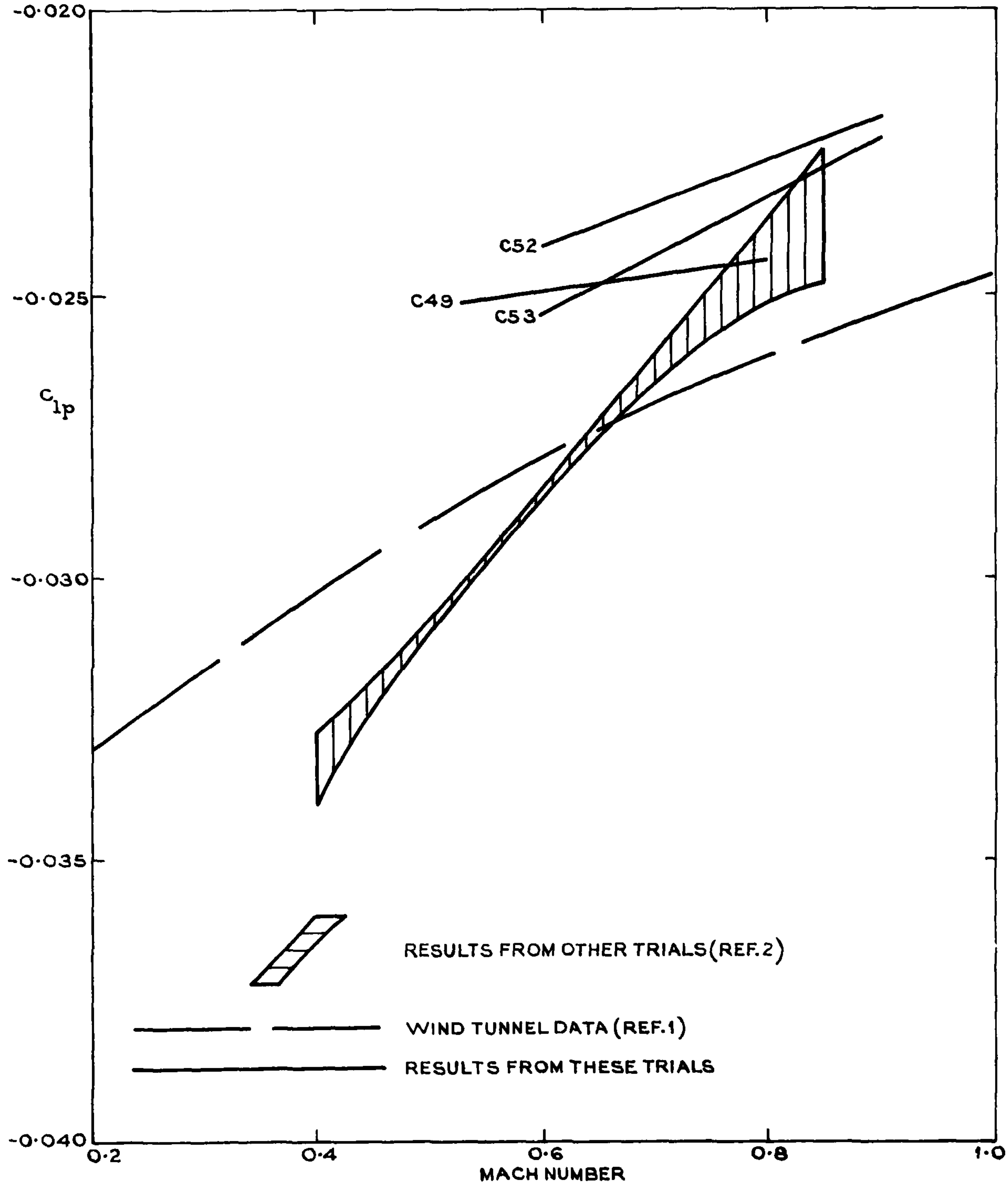

Figure 1. Roll Damping Moment Results

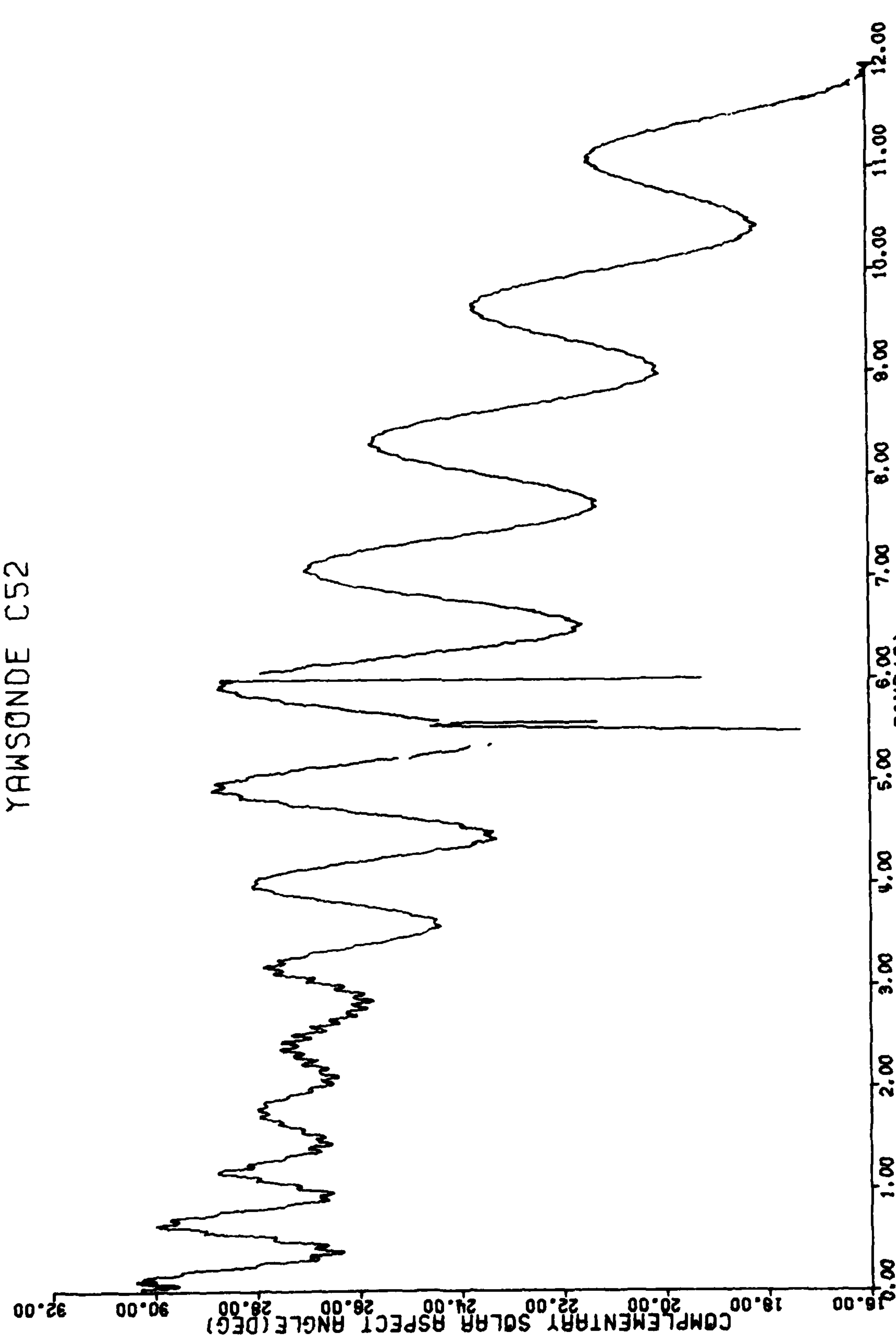

Figure 2. Solar Aspect Angle Measurements with WSRL Yawsondes
(a) Round C52

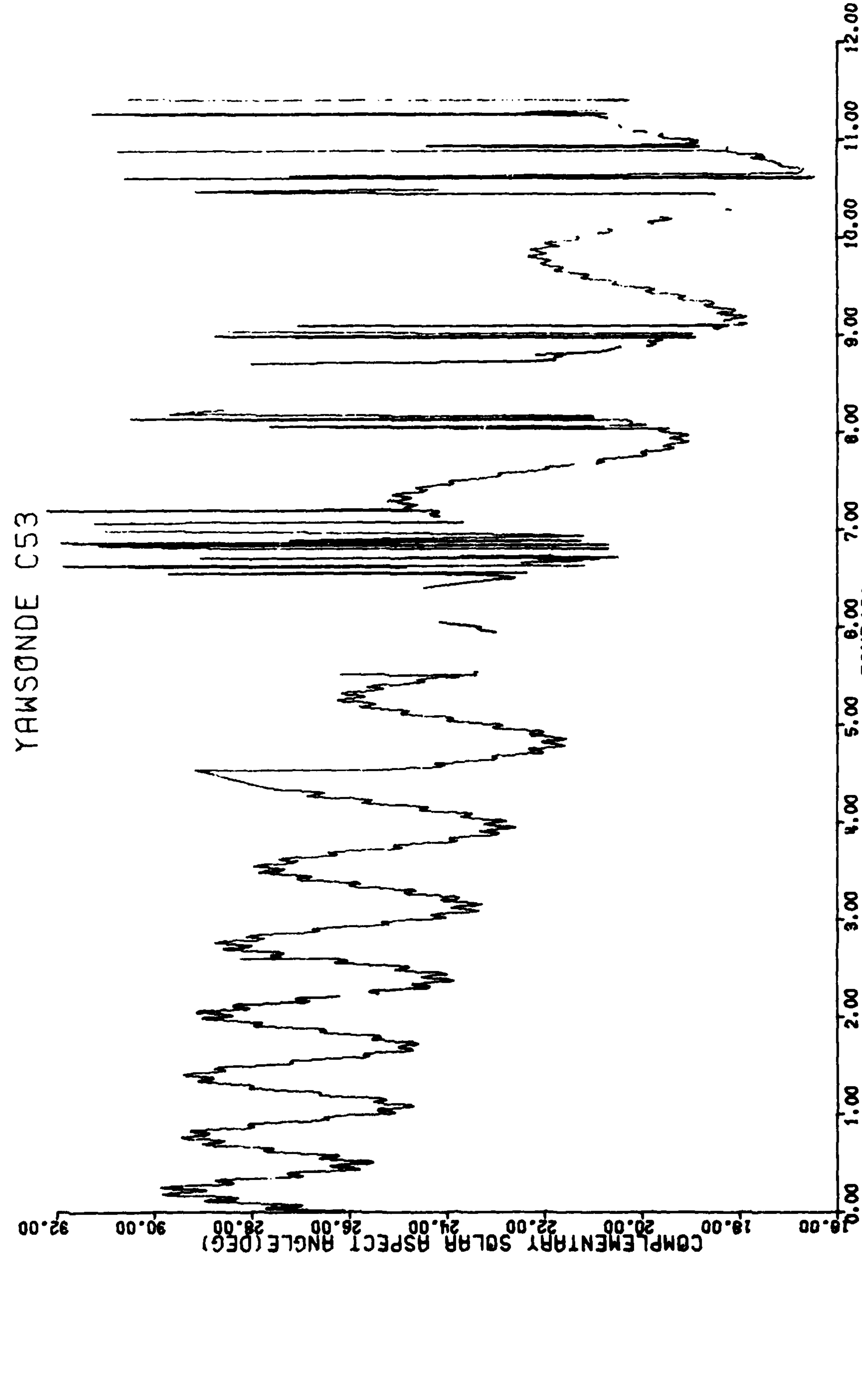

Figure 2. Solar Aspect Angle Measurements with WSRL Yawsondes
(b) Round C53

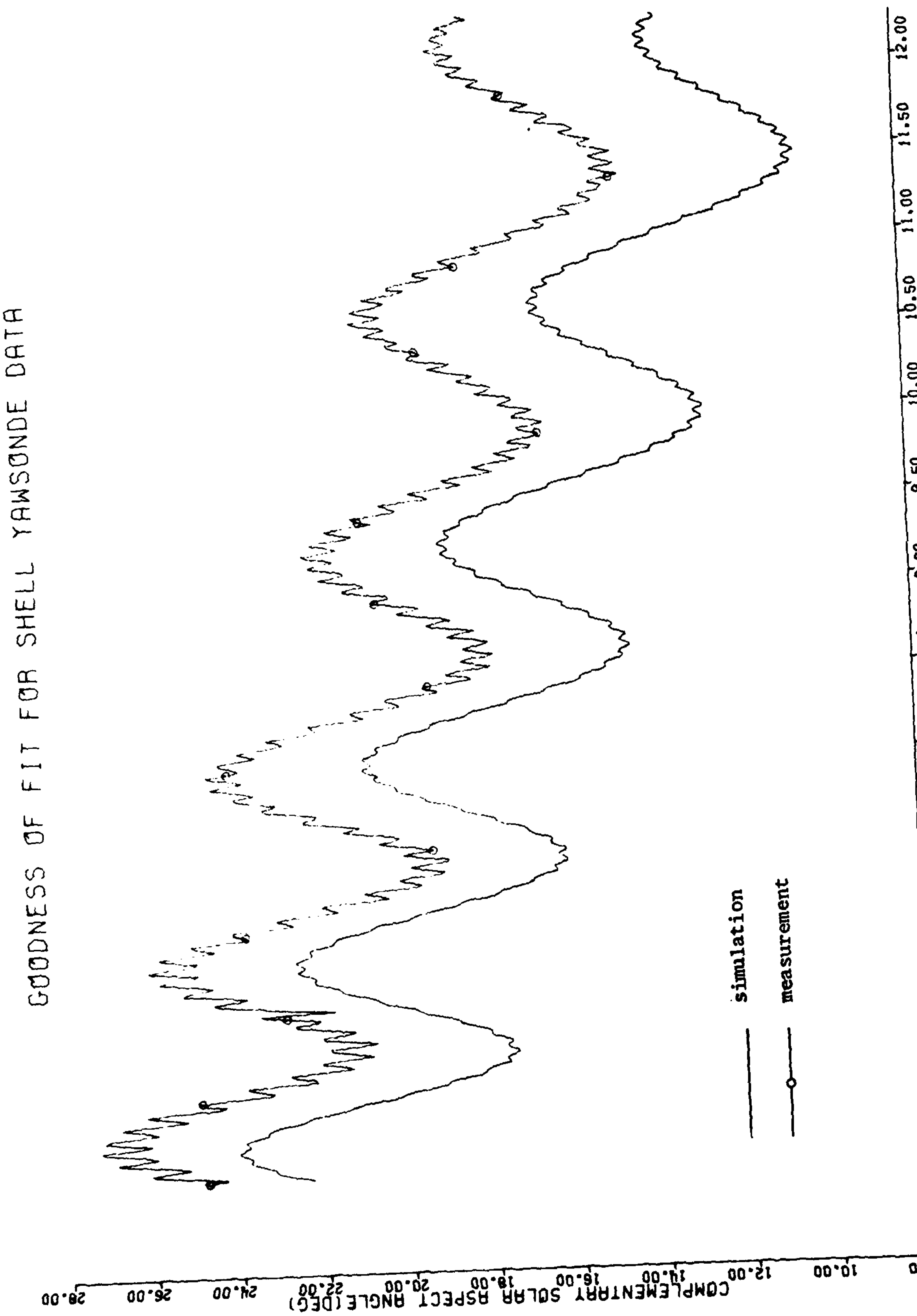

Figure 3. Solar Aspect Angle Simulation from Round C49
(a) Original Timing

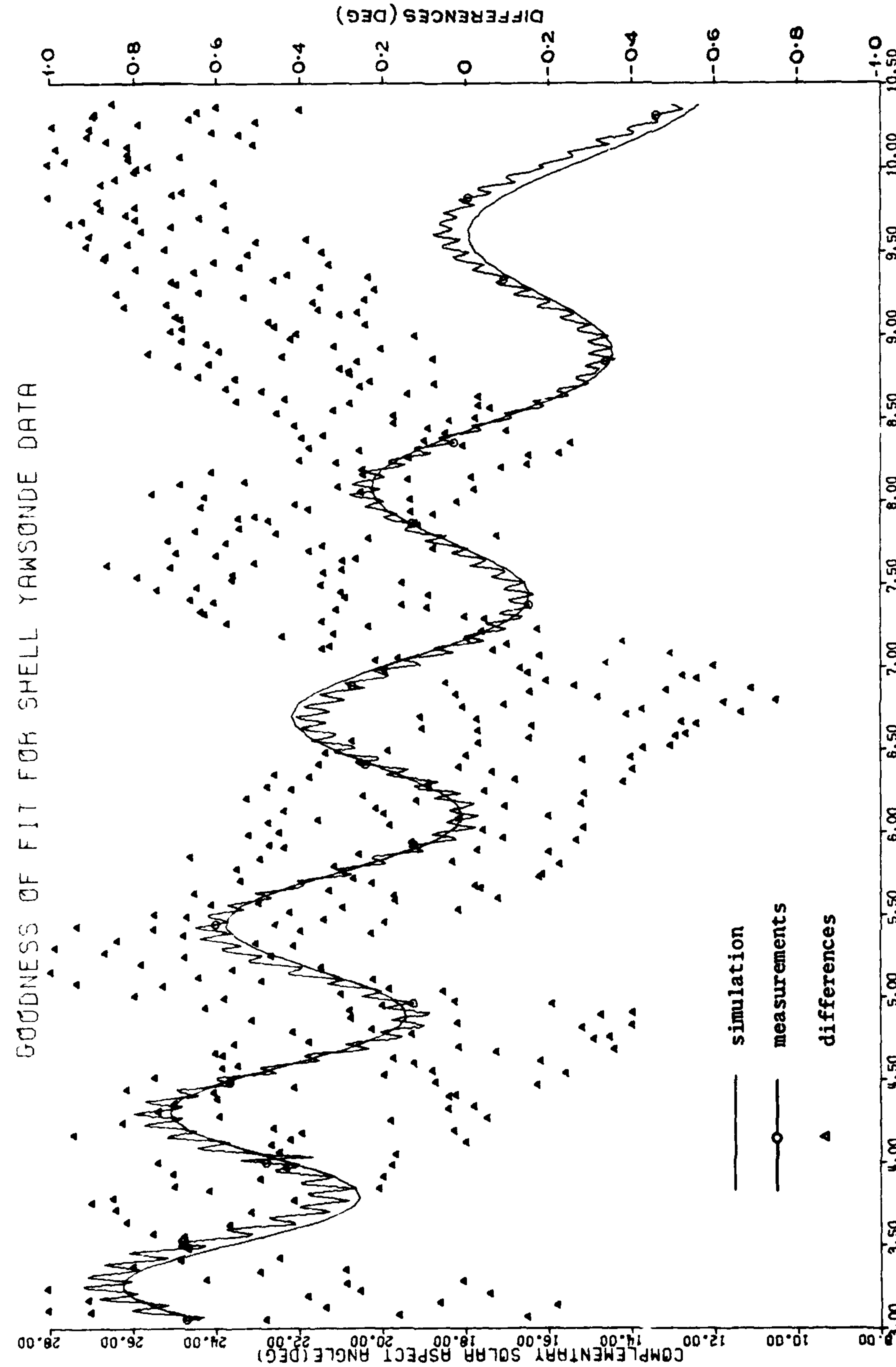

Figure 3. Solar Aspect Angle Simulation from Round C49
(b) Adjusted Timing

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